

MANUFACTURING POLYMER THIN FILMS
IN A MICRO-GRAVITY ENVIRONMENT

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ABSTRACT

This project represents Venezuela's first scientific experiment in space.

The apparatus for the automatic casting of two polymer thin films will be contained in NASA's Payload No. G-559 of the Get Away Special program for a future orbital space flight in the U.S. Space Shuttle.

Semi-permeable polymer membranes have important applications in a variety of fields, such as medicine, energy, and pharmaceuticals and in general fluid separation processes, such as reverse osmosis, ultra-filtration, and electrodialysis.

The casting of semi-permeable membranes in space will help to identify the roles of convection in determining the structure of these membranes.

INTRODUCTION

The idea of casting semi-permeable polymer membranes in a micro-gravity environment was developed by the author in 1984 after experimental evidence showed that the morphological structure of these synthetic membranes is affected by convection forces.

The Get Away Special program was selected after several weeks of learning and understanding the NASA procedures and opportunities available to scientists wishing to do space experimentation. It was recognized that this program would require an automatic system to be developed for the performance of the experiment.

Special design considerations were taken in order to ensure the construction of an apparatus which could successfully handle the fluids involved in this experiment.

JUSTIFICATION

The formation of porous membranes by the coagulation of a polymer solution in a non-solvent bath (phase inversion technique) has been studied intensively in the last few years. Despite the great advances

in membrane technology and its applications, there is a need to improve the fundamental understanding of the mechanism governing membrane formation and its structure.

This proposed research is based on reported phenomena concerning the specific gravity contribution to the molecular morphology of polymer membranes.

In at least two steps (evaporation step and gelation step) of the Phase Inversion Casting Mechanism, the differences in specific gravity between the cast polymer solution and the coagulating liquid affect the entire structure of the polymer films.

During the evaporation step the removal of the solvent breaks the thermo-dynamic equilibrium of the polymer structure. When the process is dominated by convection forces, the violent movement of polymer aggregates and hence their coalescence causes the formation of large voids or imperfections (Figure 1).¹

During the gelation step the convection flows of solvent and solvent non-solvent mixtures through the cast layer interface prevail concurrently with the diffusive exchange of solvent with non-solvent. When the differences in specific gravity are high, the coagulation is controlled by convection rather than diffusion and dense, tight semi-isotropic membranes are formed (Figure 2). The structure of these membranes are far from the ideal anisotropic porous structure (Figure 3).²

By casting the membranes in a micro-gravity environment, the effect of convection upon these polymer films can be identified. Furthermore, membranes with a better morphological structure and membranes with fewer imperfections might be produced.³

EXPERIMENT DESCRIPTION

A schematic of the experiment concept is presented in Figure 4, along with the desired sequence. The experiment will be conducted in one-half of a 5 cubic-foot cylinder, as shown in Figure 5.

An apparatus for the automatic casting of two polymer films of different chemical compositions has been designed. The casting will be performed simultaneously and will be followed by flushing with cold water.

The payload has an active heating subsystem. The plan to maintain the temperature between the limits of 0°C and 30°C is to allow the ambient thermal conditions in the Orbiter bay to drive the temperature down to near 0°C passively. If the temperature reaches this low level, a thermo-stat will activate strip heaters to elevate the temperature to values between 10°C and 20°C.

The membrane casting apparatus will be contained in NASA's payload No. G-559 of the Get Away Special program for a future flight in the U.S. Space Shuttle. This payload will also contain a protein crystal

growth experiment and a cell growth experiment, both being developed by the Bioprocessing and Pharmaceutical Research Center of the Philadelphia University City Science Center.

The whole system with the experiments, structure, and avionics will be subjected to acceleration, vibration, and thermal-vacuum tests replicating launch and space conditions.

EXPERIMENTAL METHODOLOGY

The conditions for the casting of polymer membranes in a micro-gravity environment will replicate as closely as possible the conditions under which polymer membranes are produced on earth (i.e. pressure, temperature, humidity, etc.) All of these conditions will be recorded in space.

Once on earth, the membranes cast in space will be tested in three general areas:

Transport Ability:	Reverse Osmosis, Dialysis, Ultrafiltration;
Mechanical Testing:	Young Modulus, Collapse Pressure; and
Morphology Analysis:	Scanning Electron Microscope, Wet test, dry test.

PROGRESS

This project was initiated at the end of 1984 with the support of the Venezuelan Government through the National Electric Company of Venezuela.

The design phase and safety analysis have been completed. Fabrication, testing, and integration of the prototype unit and of the prime flight hardware are expected to be completed by the end of 1986.

CONSULTATIONS

Throughout the development of this project, several scientific institutions have offered their guidance, advice, and encouragement. They include:

1. The Bioprocessing and Pharmaceutical Research Center of the U.C.S.C. of Philadelphia;
2. The Polymer Research Institute of the State University of New York;
3. The Chemistry Department of the National Research Council of Canada;
4. The Energy Center and the Chemical Engineering Department of the University of Pennsylvania.

REFERENCES

- ¹Matsuura, Takeshi. "Scientific Justification for Research on Membrane Preparation under Micro-Gravity Environment." Unpublished document directed to Ivan Vera. Division of Chemistry, National Research Council of Canada. March 24, 1986.

- ²Cabasso, Israel. "Ultrastructure of Asymmetric and Composite Membranes." American Chemical Society Symposium Series, 153. Volume 1, Desalination. Tubark, Albin F., Editor, 1981. Pp. 267-291.
- ³Vera, Ivan. "The Casting of Semi-Permeable Membranes in a Micro-Gravity Environment." 1985 Get Away Special Experimenters Symposium. NASA Conference Publication 2401. October 1985, pp. 41-47.

FIGURES

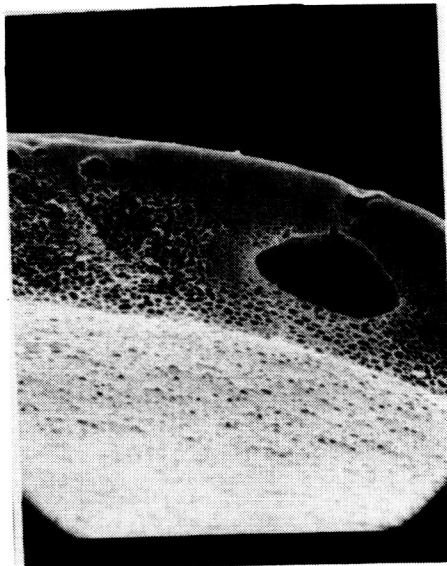


FIGURE 1. Micrograph of Cross-Section of
a Polymer Membrane Exhibiting a Macrovoid
(SEM - 800 mag.)

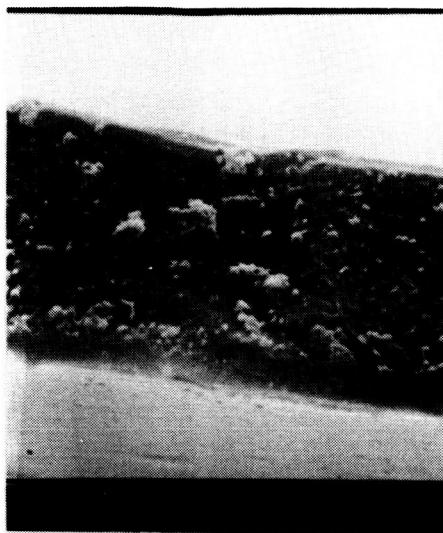


FIGURE 2. Micrograph of Cross-Section of
a Dense Semi-Isotropic Polymer Membrane
(SEM - 2500 mag.)

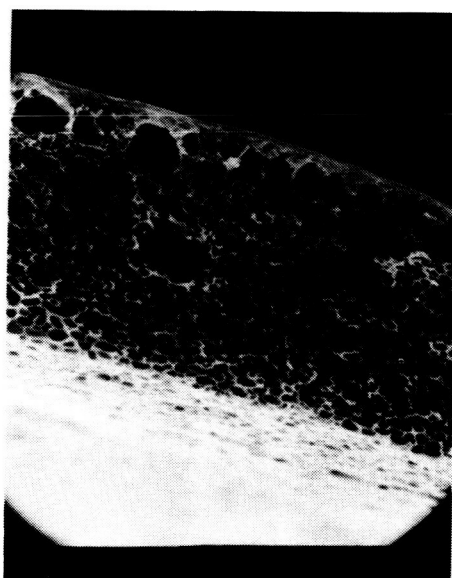


FIGURE 3. Micrograph of Cross-Section of
a Porous Anisotropic Polymer Membrane
(SEM _ 1400 mag.)

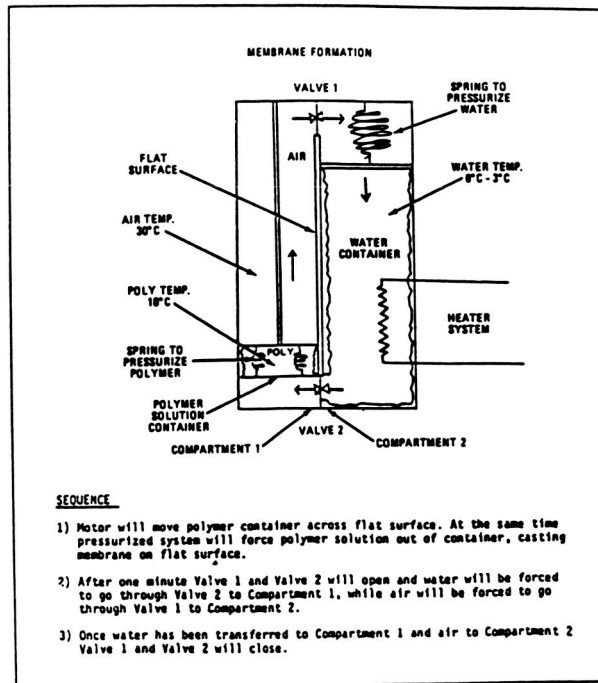


FIGURE 4. Experiment Concept

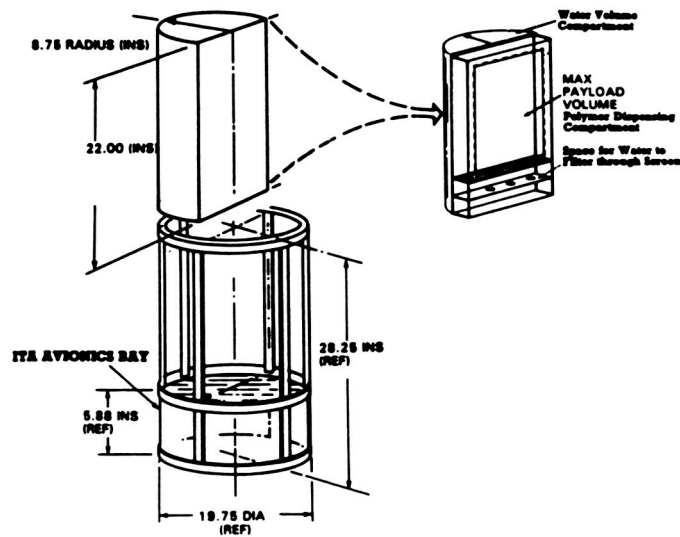


FIGURE 5. Longitudinal Cylinder